MIAMI-DADE COUNTY PUBLIC SCHOOLS
OFFICE OF EVALUATION AND RESEARCH
1500 BISCAYNE BOULEVARD
MIAMI, FL 33132

EVALUATION OF THE COGNITIVE TUTOR ALGEBRA I PROGRAM

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Principal Evaluator/Author: Alex Shneyderman

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EXECUTIVE SUMMARY

Carnegie Learning's Cognitive Tutor Algebra I program is designed to provide students with an opportunity to learn Algebra I in both classroom and computer lab settings. Students spend about forty percent of instructional time in their algebra classes interacting with the Cognitive Tutor software. The software is designed to "understand" the methods a student may use to solve a problem and to offer individualized assistance to the student. The computer program adapts to the student by pacing the curriculum and by selecting problems according to the student's needs. About sixty percent of instruction takes place in a classroom setting, where students usually work in small groups. The Cognitive Tutor Algebra I program is currently used in hundreds of schools nationwide. The program was shown to improve student achievement on standardized test items (especially on constructed-response or performance items), enhance levels of student understanding of mathematics, and increase student engagement in the learning process. Within the Miami-Dade County Public Schools, the program was used in nine senior high schools during the 2000-2001 school year. The Division of Mathematics and Science requested this evaluation of the 2000-2001 Cognitive Tutor Algebra I program

To investigate effects of the program on student learning, two student groups, the Program and Comparison Samples, were established. Students in these groups were selected from six of the nine program schools (those in which computer labs were operational by October 2000). Students in the Program Sample (325 in all) used the Cognitive Tutor Algebra I software, whereas their counterparts in the Comparison Sample (452 in all) did not. Educational Testing Service's (ETS) Algebra I Test and the Norm-Referenced Component of the Florida Comprehensive Assessment Test (FCAT-NRT) were used to measure student mathematics performance. End of year Algebra I passing rates and final grades were considered as well. Additionally, student attitudes toward mathematics were assessed. Finally, 18 teachers participating in the program were surveyed to determine their reactions to it.

The evaluation questions and results are presented below.

Evaluation Question 1: Does the program increase student academic achievement?
Students in the Program group exhibited significantly higher results on the ETS Algebra I Test than did students in the Comparison Group. This higher algebra performance was more apparent for male students than it was for female students. In addition, proportions of students who passed the Algebra I course and of those who earned grades of "C" or above were somewhat higher for students in the Program Sample than they were for students in the Comparison Sample. However, the overall mathematics and algebra performances measured by the 2001 FCAT-NRT were comparable for students in the two groups. Overall, the findings appear to indicate that the program had a positive impact on student achievement in Algebra.

Evaluation Question 2: Does the program improve students' attitudes toward mathematics? Students in the Program Sample, as a group, exhibited significantly higher confidence in their abilities to learn mathematics than did their counterparts in the Comparison Sample. Students in both student groups showed about the same level of perception of mathematics as a useful subject. These findings suggest that the program had a beneficial effect on student confidence in learning mathematics.

Evaluation Question 3: What are the teachers' views on the effectiveness of the program? Most teachers participating in the program expressed favorable opinions about the effects of the program on student learning, indicating that the program increased student motivation to learn Algebra, made Algebra more interesting and/or relevant, and helped teachers to individualize and adjust their instruction.

Based on these findings, the following recommendations are offered:

1. Continue the Carnegie Learning Cognitive Tutor Algebra I Program in the schools involved.

2. Reevaluate the program during the 2001-2002 school year.

INTRODUCTION

Carnegie Learning's Cognitive Tutor Algebra I Program is designed to offer students an opportunity to learn algebra in both the classroom and in the computer lab environments. The program covers a full year Algebra I course. Students normally spend 2 days per week working with the Cognitive Tutor™ in the lab and 3 days per week working on small-group activities in the classroom. The program integrates multiple resources such as student and teacher editions of textbooks, and computer software. Students proceed through a problem by reading its description and a number of questions about it. Then, they explore the situation by representing it in tables, graphs, and symbols and using these to answer the questions. The Cognitive Tutor software is designed to “understand” methods that a student may use to solve a problem, so it can provide individualized levels of help to support the student’s effort at each step. It customizes problems selected for each learner and paces the curriculum based upon his or her needs. It progressively “learns” about the student's comprehension and ability levels by means of monitoring the process of problem solving. The Cognitive Tutor software then adapts the curriculum to each student and selects problems accordingly. Student progress, visible to both the student and teacher, is displayed on the screen at all times. In addition, the teacher can generate detailed reports of student progress.

Literature on the subject of the Cognitive Tutor Program reports several benefits of the Program including improved student achievement on standardized test items (especially on constructed-response or performance items), improved levels of student understanding of mathematics, and increased student engagement in the learning process (Davidson, 1996; Koedinger, Anderson, Hadley and Mark, 1998).

Within Miami-Dade County Public Schools, there were nine senior high schools using the Cognitive Tutor Algebra I Program in the 2000-2001 school year. Most of the students in the program were ninth graders and were studying Algebra I for the first time.

The evaluation of the Cognitive Tutor Algebra I Program was intended to explore students’ instructional outcomes and attitudes toward mathematics, as well as teachers’ opinions about the program. More specifically, the evaluation attempted to answer the following questions:

> **Evaluation Question 1:** *Does the program increase student academic achievement?*
>
> **Evaluation Question 2:** *Does the program improve students’ attitudes toward mathematics?*
>
> **Evaluation Question 3:** *What are the teachers’ views on the effectiveness of the program?*

METHOD OF EVALUATION

Sample Selection. One of the major components of the Cognitive Tutor Algebra I Program is its extensive use of computer technology: students in the program were spending about 40% of their instructional time in the computer lab. Of the nine schools participating in the program, six had computer labs completed by October 2000. Accordingly, only students from these schools were considered for academic achievement and attitude comparisons. To answer the evaluation questions posed, two samples of students were created. For every selected school, two teachers were randomly selected from among all teachers participating in the program, excluding those working with classes of predominantly Exceptional Education students. Subsequently, for each selected teacher, one of his/her classes exposed to the program was randomly selected. Twelve classes were chosen in this manner. Students in the chosen classes constituted the **Program Sample**. The **Comparison Sample** comprised students from an equal number of randomly selected Algebra I classes not in the program in each of the six selected schools. Some demographic characteristics of students in the two students groups are presented in Table 1.

TABLE 1

STUDENTS' DEMOGRAPHIC CHARACTERISTICS

STUDENT CHARACTERISTICS		**PROGRAM SAMPLE (N = 325)**	**COMPARISON SAMPLE (N = 452)**
RACE/ETHNICITY	Black	30%	27%
	Hispanic	56%	62%
	White	13%	10%
	Other	1%	1%
GENDER	Females	46%	48%
	Males	54%	52%
STUDENTS ON FREE OR REDUCED LUNCH		54%	54%
LIMITED ENGLISH PROFICIENCY STUDENTS		9%	20%

It can be seen that the proportions of students on free/reduced lunch were identical, and that the ethnic and gender distributions were very similar for the two student groups, indicating that the groups were comparable in terms of their background characteristics.

Almost all students in both samples were either ninth or tenth graders. About 79% of students in the Program group and 88% of students in the Comparison group were ninth graders. Tenth grade students accounted for 18% of the total in the Program group, and for 11% in the Comparison group. Only about 3% of students in the Program group and about 1% of students in the Comparison group were in grades 11 or 12. Therefore, the comparison of mathematics performance exhibited at the end of 1999-2000 school year was carried out only for 9th and 10th grade students in the two groups. It revealed that students in both groups performed at practically identical levels. The average FCAT-NRT 9th grade scale scores were 659.6 and 660.5 for students in the Program and Comparison Samples respectively. Similarly, these scores for 10th graders were 676.8 for students in the Program group and 677.2 for their counterparts in the Comparison Sample. The mathematics FCAT-NRT results did not differ significantly for female and male students in either 9th or 10th grade. Virtually identical levels of mathematics performance indicate that students in the two groups were comparable academically. Therefore, no statistical adjustment for the prior achievement was necessary when making algebra performance comparisons.

Academic Comparisons. The algebra performance of students in the program and that of their counterparts was measured by two instruments: the 2001 FCAT-NRT and the Educational Testing Service's Algebra I End-of-Course Assessment. (In the following text, it will be referred to as the ETS Algebra I Test). The ETS Algebra I Test included 25 multiple-choice and 3 constructed-response (or performance) items. Each of the latter items contained four parts, progressively increasing in level of difficulty. Students were asked to provide their own solutions to the problems posed in the constructed-response part of the test. The results of the test were available in several formats including raw scores on the multiple-choice and constructed-response parts of the test, the composite scale scores, and level of understanding ratings. These ratings varied from one to four, denoting minimal, basic, proficient, or advanced levels of algebra understanding. A complete description of these levels is given in Appendix A. The mathematics FCAT-NRT test consisted of 48 multiple-choice questions in 10 areas ranging from problem solving to Precalculus. The mean scale scores on the ETS Algebra I Test and those on the 2001 FCAT-NRT were statistically compared (using the independent-samples t-test) for students in the two groups. In addition, the levels of algebra understanding ratings reported by ETS were contrasted for students in the two samples. The ETS Algebra I Test results were available for 235 students in the Program Sample and for 321 students in the Comparison Sample. The FCAT-NRT results were available for 226 and 340 in the Program and Comparison Samples respectively. Additionally, the Algebra I passing rates and final grades earned by students in the two samples were compared. These data were available for 306 students in the Program and 411 students in the Comparison group.

Mathematics Attitude Comparison. The modified Fennema-Sherman Attitude Scale (see Appendix D) was used to measure attitudes toward mathematics for students in the two samples. This instrument contained four different subscales, of which the scales entitled "Personal Confidence about Mathematics" and "Perception about Usefulness of Mathematics" were used. Each of these subscales consisted of 12 items. An independent-samples t-test was used to compare the average measures of confidence about learning mathematics and those of usefulness of mathematics for students in the two groups. The students' scores on these subscales were available for 278 students in the Program Sample and for 308 students in the Comparison Sample.

Teacher's Survey. Teachers participating in the program were surveyed. The Teacher Questionnaire (see Appendix B) was used to assess teachers' reactions to the Cognitive Tutor Algebra I Program. The questionnaire consisted of nine true/false questions that were intended to measure respondents' views of the program and one open-ended question asking teachers to provide their comments or suggestions regarding the program. In all, 25 teachers in each of the 9 schools participating in the program were asked to complete the survey. Eighteen completed questionnaires were returned (72% return rate).

RESULTS AND DISCUSSION

This section provides the findings and their implications for each evaluation question individually.

Evaluation Question 1: Does the program increase student academic achievement?

The academic achievement comparisons were based on the results of the ETS Algebra I Test, the norm-referenced component of the Florida Comprehensive Assessment Test, and on student end of year Algebra I outcomes. The results are presented below.

The ETS Algebra I Test outcomes. The results of the comparison of the mean scale scores on the ETS Algebra I Test for students in the two groups indicate that students in the Program Sample scored significantly higher ($p < .01$) than their counterparts in the Comparison Sample. The average scale score of students in the program was 10.8 compared to 9.6 for students not in the program. The difference of the mean scale scores for students in the two groups represents an effect size of .22. To put this number in perspective, a student with an average achievement in the program group outperformed about 58% of students in the comparison group. Such an effect size is traditionally considered as small meaning that, although the algebra performances of students in the two groups differed, this difference may not have been significant in a practical sense. Performance of students in the two groups can further be described as follows. The students in both the Program and Comparison Samples on the average answered 9 out of 25 multiple-choice questions correctly. The students in the Program Sample outperformed their counterparts in the Comparison group on the constructed-response (or performance) part of the test, earning an average score of 4.9 out of the maximum possible score of 29. This compares favorably to the average score of 3.6 earned by students in the Comparison Sample on the same part of the test. Additionally, the average scale score of students in the Program Sample corresponds to the 14th percentile in the National Norm Sample, whereas that of students in the Comparison Sample corresponds to the 11th percentile. These results are shown in Table 2.

TABLE 2.

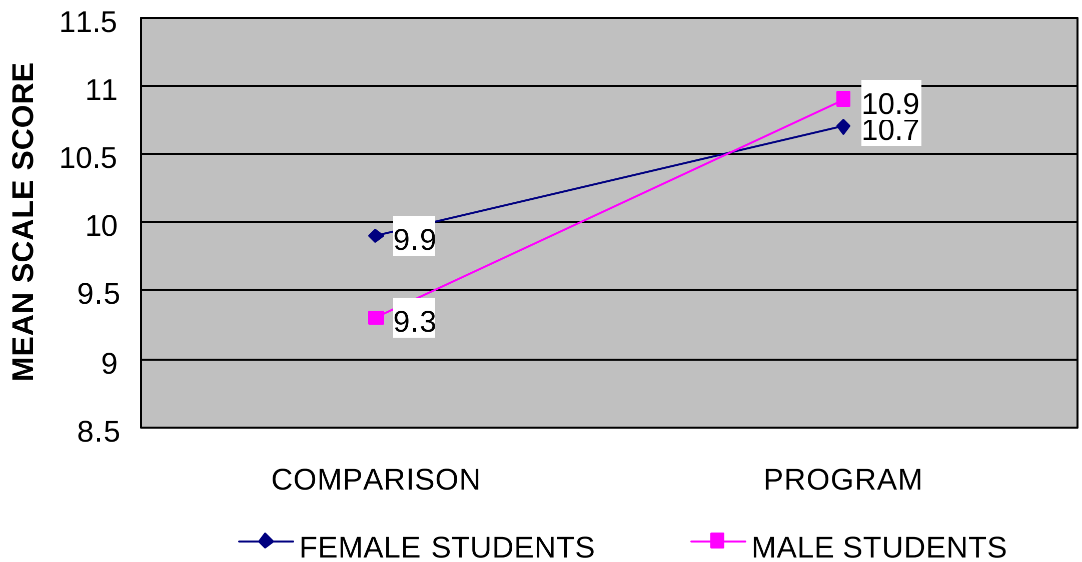
STUDENTS' ETS ALGEBRA I TEST RESULTS

ACHIEVEMENT RESULTS	**PROGRAM SAMPLE (N = 235)**	**COMPARISON SAMPLE (N = 320)**
MEAN SCALE SCORE	10.8	9.6
CORRESPONDING PERCENTILE	14	11
AVERAGE MULTIPLE-CHOICE SCORE	9.0	9.0
AVERAGE CONSTRUCTED-RESPONSE SCORE	4.9	3.6

The Cognitive Tutor Algebra I Program involves extensive human-computer interactions. It is known that sometimes male and female students react differently to computer technology. The present results show that male students in the program outperformed their counterparts not in the program by a larger margin than female students did. Male students in the program scored 10.9 on average compared to 9.3 for those not in the program, a difference of 1.6 units, which is statistically significant ($p < .01$). At the same time, female students in the Program Sample achieved the average scale score of 10.7 compared to 9.9 for those in the Comparison Sample, a difference of .6 units, which is not statistically significant. These results are shown in Figure 1.

FIGURE 1

STUDENTS' ACHIEVEMENT BY GENDER



In addition to providing achievement results in terms of scale scores, ETS assigns each student a level of understanding. These levels range from one to four denoting the minimal, basic, proficient, or advanced levels of understanding of Algebra I concepts. The distribution of students by their levels of algebra understanding is shown in Table 3. It can be seen that about one-half of students in both the Program and Comparison Samples (approximately 45% and 50% respectively) exhibited the lowest, minimal level of understanding. Close to one-half of students in the two groups achieved the basic (next to lowest) level of understanding. These percentages were 48% for students in the program group, and 44% for their counterparts in the comparison group. The proportions of students with proficient or advanced levels of algebra understanding were very small (approximately 7% and 6% for students in the program and comparison groups respectively) and did not differ substantially. These results were somewhat different from those exhibited by students assessed nationally by the ETS Algebra I test in June of 2001. About one-tenth of them (13%) attained the minimal level of algebra understanding, less than one-half (43%) attained basic, 31% attained proficient, and 13% attained advanced level of comprehension of Algebra I concepts.

TABLE 3

STUDENTS' LEVELS OF ALGEBRA UNDERSTANDING

LEVELS OF UNDERSTANDING	**PROGRAM SAMPLE** (N = 235)	**COMPARISON SAMPLE** (N = 320)	**NATIONAL RESULTS** (N = 13021)
MINIMAL LEVEL	45.1%	49.5%	13%
BASIC LEVEL	48.1%	44.5%	43%
PROFICIENT LEVEL	6.0%	5.9%	31%
ADVANCED LEVEL	0.9%	0.0%	13%

Note: percentages do not add up to 100% due to the round-off error.

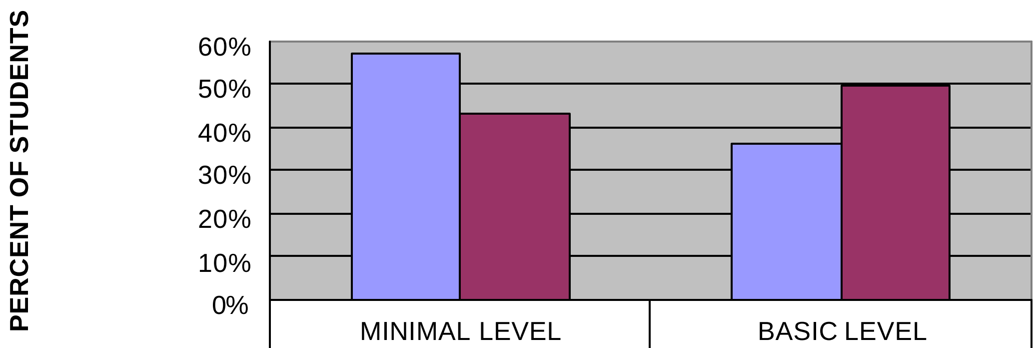
When the distributions of students by their levels of algebra understanding were analyzed by gender, it was found that male and female students were distributed differently. Since almost all students in either group (93%-94%) attained one of the two lower (minimal or basic) levels of understanding, the gender differences in the patterns of achievement will be outlined below for students on these two levels.

As shown in Figure 2, there were fewer Program Sample male students achieving the lowest (minimal) level of understanding (43%) than those reaching the next higher (basic) level of algebra understanding (about 50%). Male students in the Comparison Sample were distributed in a different way: more of them (57%) performed at the lowest (minimal) and smaller proportion of them (36%) reached the higher (basic) level of understanding. These figures suggest that male students benefit from the program with larger proportions of them achieving a higher level of algebra understanding, compared with those not in the program.

The distributions of female students attaining the same two lower levels of algebra understanding seem to have taken the opposite direction (see Figure 3). Practically equal proportions of program group female students (about 47%) achieved each of the two lowest levels of understanding (minimal or basic). On the other hand, a smaller proportion of comparison group female students reached the lowest (minimal) level of understanding (about 42%), whereas larger part (53%) achieved the next higher (basic) level. These numbers seem to imply that female students did not benefit from the program as much as their male counterparts did.

FIGURE 2

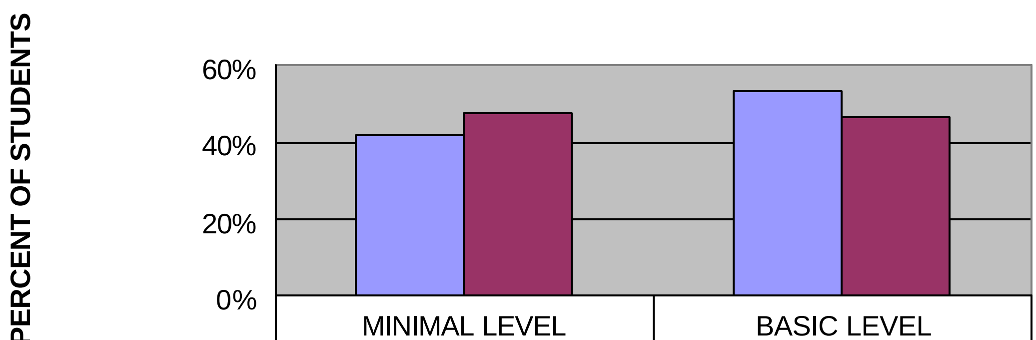
LEVELS OF UNDERSTANDING FOR MALE STUDENTS



	MINIMAL LEVEL	BASIC LEVEL
COMPARISON	57.1%	36.0%
PROGRAM	43.0%	49.6%

FIGURE 3

LEVELS OF UNDERSTANDING FOR FEMALE STUDENTS



	MINIMAL LEVEL	BASIC LEVEL
COMPARISON	41.9%	53.1%
PROGRAM	47.4%	46.5%

These findings appear to indicate that the program is more suitable for male students' learning styles than it is for those of female students.

The FCAT-NRT outcomes. The results of the comparison of the mathematics 2001 FCAT-NRT results indicate that the mean scale scores of students in the Program and Comparison groups did not differ significantly. As shown in Table 4, the mathematics mean scale scores were approximately 682.7 for 9th grade students in the Program Sample and 681.1 for their counterparts in the Comparison Sample. For the 10th grade students, the mathematics mean scale scores were 688.0 and 693.6 for students in the Program and Comparison groups respectively. These performance figures can be described in the following way: an average 9th grade student in the Program group answered approximately 21, out of the 48 multiple-choice test questions correctly, whereas an average 9th grade student in the Comparison group answered about 20. For the 10th graders, an average student in the Program Sample achieved an approximate raw score of 19, and an average student in the Comparison Sample scored approximately 21 on a scale from 0 to 48. The mathematics FCAT-NRT results did not differ significantly for female and male students in either 9th or 10th grade. Therefore, these results were not disaggregated by gender.

TABLE 4

STUDENTS' FCAT-NRT RESULTS

ACHIEVEMENT RESULTS		**PROGRAM SAMPLE**	**COMPARISON SAMPLE**
MEAN MATHEMATICS SCALE SCORE	9th grade	682.7	681.1
	10th grade	688.0	693.6
MEAN MATHEMATICS MULTIPLE-CHOICE SCORE	9th grade	20.7	20.4
	10th grade	19.2	21.0
MEAN ALGEBRA MULTIPLE-CHOICE SUBSCORE	9th grade	3.9	3.8
	10th grade	3.3	3.3

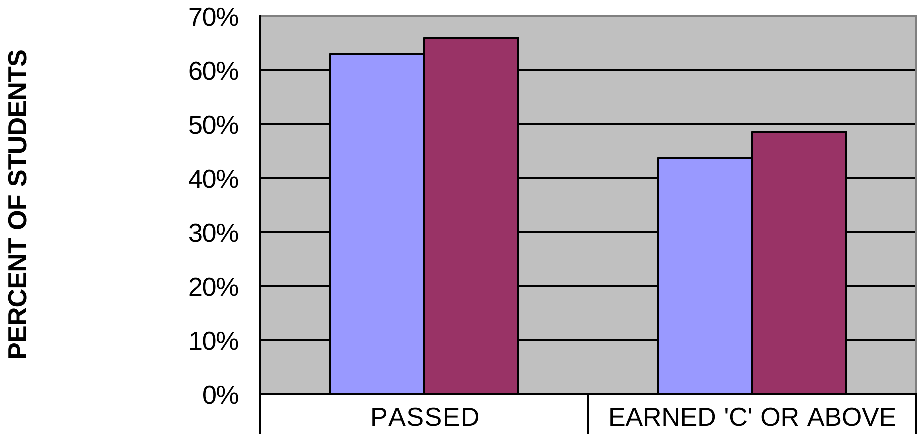
Note: the figures in the table are based on the following sample sizes. The Program Sample: 226 students in 9th grade, and 50 students in 10th grade; The Comparison Sample: 340 students in 9th grade and 42 students in 10th grade.

Students in both groups exhibited similar performance on the algebra cluster of the mathematics FCAT-NRT. The 9th grade students in both groups answered approximately four, and the 10th grade students in both groups answered about 3 out of 6 questions correctly.

End of year Algebra I outcomes. Passing rates and final Algebra I grades were compared for students in the two groups. As shown in Figure 4, the passing rate was somewhat higher for students in the program: 66% of them passed the Algebra I course in June of 2001, whereas only 63% of students in the Comparison Sample did. Similarly, a larger proportion of students in the Program group (48%) earned final grades of "C" or above compared to the corresponding figure of 44% for students in the Comparison group. Nearly equal proportions of students in both groups earned final grades of "A" or "B". Very few students (less than 2%) earned final grades of "A", and about 11% of students earned final grades of "B". The proportions of students receiving final grades of "C" were about 36% for the Program group, and 30% for the Comparison group. About 34% of students in the Program Sample earned final grades of "D" compared to 37% for students in the Comparison group earning that grade.

FIGURE 4

STUDENTS' END OF YEAR ALGEBRA I RESULTS



	PASSED	EARNED 'C' OR ABOVE
COMPARISON	62.8%	43.6%
PROGRAM	66.0%	48.4%

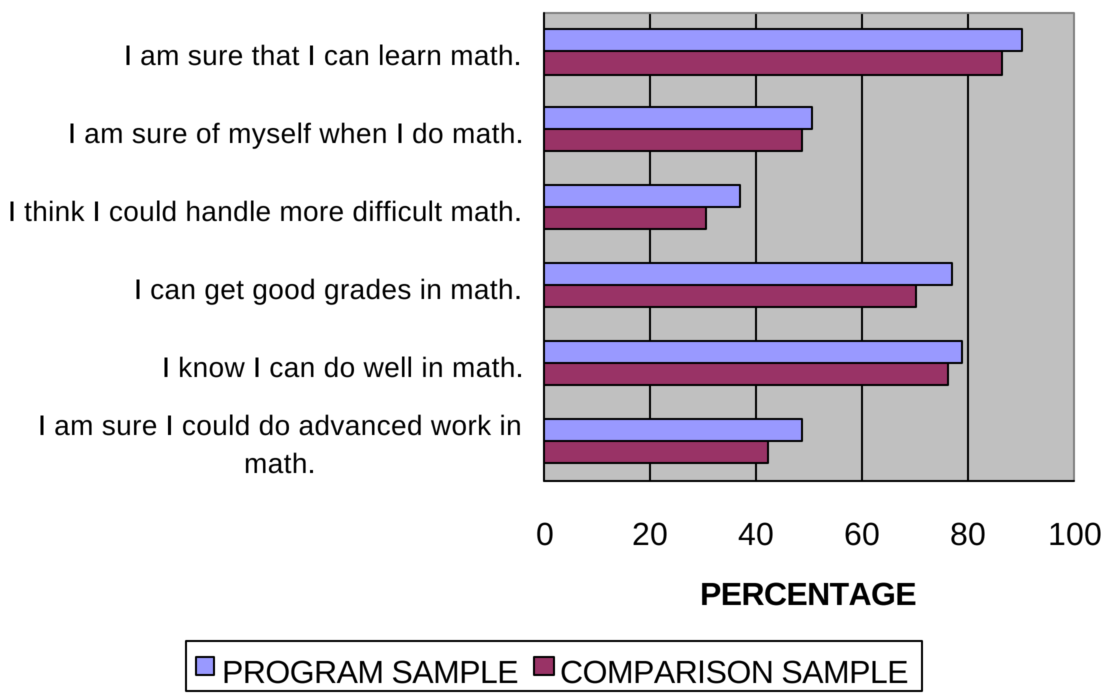
Summary for Evaluation Question 1: It should be noted that only one of the schools evaluated had its computer lab operational by the beginning of the 2000-2001 school year. Other schools had computer labs ready later during the school year (but not later than by October 2000). Consequently, it is possible that the full benefits of the program could not have materialized. Nevertheless, students in the Program group exhibited significantly higher results on the ETS Algebra I Test than did students in the Comparison Group. It should be noted that this higher algebra performance was more apparent for male students than it was for female students. In addition, proportions of students who passed the Algebra I course and of those who earned grades of "C" or above were somewhat higher for students in the Program Sample than they were for students in the Comparison Sample. However, the overall mathematics and algebra performances measured by the 2001 FCAT-NRT were comparable for students in the two groups. All these findings appear to indicate that the program had some positive impact on student achievement in Algebra.

Evaluation Question 2: Does the program improve students' attitudes toward mathematics?

To answer this question, a modified version of the Fennema-Sherman Attitude Scale was administered to students in the Program and Comparison Samples. This instrument contains four different subscales. Student responses to two of them – the scale of personal confidence about mathematics, and the scale of usefulness of mathematics, each consisting of 12 items – were statistically compared for students in the two groups. This comparison showed that students in the Program Sample, as a group, had significantly higher ($p < .05$) confidence about learning mathematics than did their counterparts in the Comparison Sample. Furthermore, proportions of students agreeing with positively worded statements that assessed students' confidence about learning mathematics were consistently higher for students in the program than for those not in the program (see Figure 5). The margin of difference, separating the opinions about mathematics confidence expressed by students in the two groups, varied between two and seven percentage points.

FIGURE 5

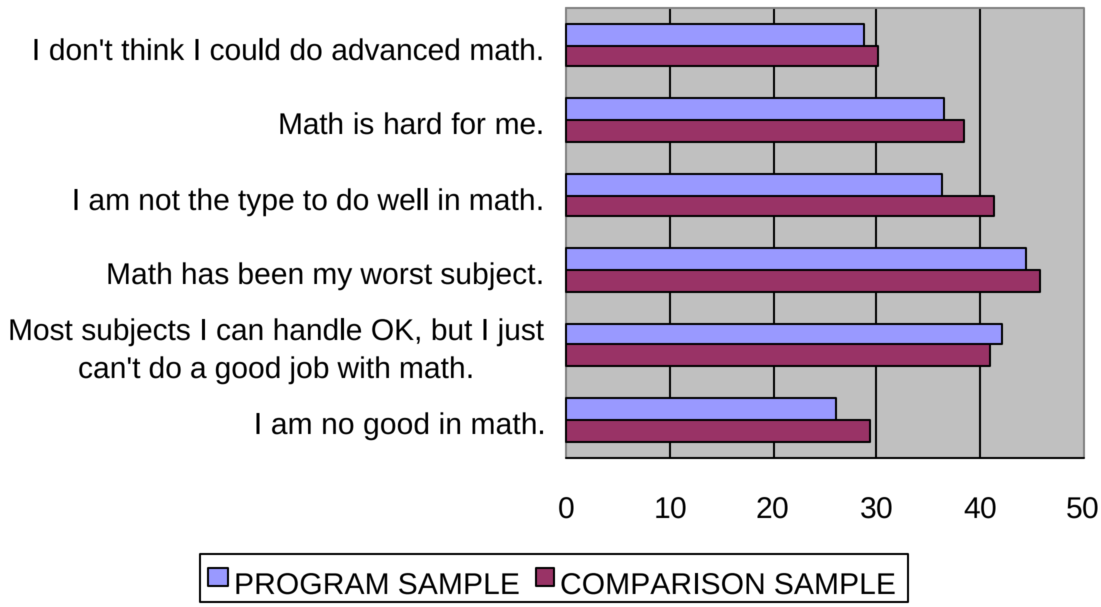
PROPORTIONS OF STUDENTS IN AGREEMENT WITH POSITIVELY WORDED STATEMENTS



Similarly, proportions of students agreeing with negatively worded statements were lower for all but one statement for students in the Program Sample than for their peers in the Comparison Sample (see Figure 6). The margin of difference varied from one to five percentage points.

FIGURE 6

PROPORTIONS OF STUDENTS IN AGREEMENT WITH NEGATIVELY WORDED STATEMENTS



Student replies to the scale of perception of usefulness of mathematics were analyzed as well. Subsequently, the average measures of perception of usefulness of mathematics were compared for students in the Program and Comparison Samples. The results showed that students' views on utility of mathematics did not differ significantly for students in the two groups. Most students in both groups agreed that mathematics was a worthwhile subject and that they would need a good understanding of mathematics for their future work. Proportions of students who expressed these opinions varied between 64% and 84% in both student samples.

Summary for Evaluation Question 2: Students in the Program Sample, as a group, exhibited significantly higher confidence in their abilities to learn mathematics than did their counterparts in the Comparison Sample. Students in both student groups showed about the same level of perception of mathematics as a useful subject. These findings suggest that the program had a beneficial effect on student confidence in learning mathematics.

Evaluation Question 3: What are the teachers' views on the effectiveness of the program?

To answer this question, all teachers participating in the program were surveyed. The responses indicate that most teachers (89%) were trained on the Carnegie Learning Cognitive Tutor Algebra I Program before the beginning of the 2000-2001 school year, and almost all teachers (95%) participated in training activities during the school year. As shown in Table 5, most teachers had favorable views on the program. About three-fourths (79%) of all teachers surveyed indicated that the program gave them more time to provide individual assistance to students. The same proportion of teachers (79%) stated that the program provided them an opportunity to adjust their instructional practices because of observing students' progression through problem solving. All teachers indicated that the program made Algebra more interesting and/or relevant to students, and almost all teachers (94%) stated that the program increased students' motivation to learn Algebra. All teachers asserted that the program had an overall positive effect on student learning.

TABLE 5

TEACHERS' VIEWS OF THE PROGRAM

STATEMENTS	**PERCENT IN AGREEMENT** ($\underline{n}$ = 19)
The program gives teachers an opportunity to adjust instructional practices because of observing students' processes of problem solving.	79%
The program gives more time to provide individual assistance to students.	79%
The program makes Algebra more interesting and/or relevant to students.	100%
The program increases student motivation to learn Algebra.	94%
Overall, the program has a positive effect on student learning.	100%

In addition to responding to true/false questions, most teachers (83%) provided comments about the program. Of those, about one-half (53%) stated that the program affected student learning in a positive way. Many of the other teachers' comments provided suggestions on how to improve the program. A complete list of all teachers' comments appears in Appendix C.

Summary for Evaluation Question 3: Most teachers participating in the program expressed favorable opinions about the effects of the program on student learning, indicating that the program increased student motivation to learn Algebra, made Algebra more interesting and/or relevant, and helped teachers to individualize and adjust their instruction.

CONCLUSIONS

The results of the ETS Algebra I Test indicate that students in the Program Sample, as a group, achieved significantly higher scores than did students in the Comparison Sample. The difference in achievement was evident on the constructed response (or performance) part of the test, not on the multiple-choice part, which appears to indicate that the program positively affects student ability to express their knowledge of important algebraic concepts and processes. Further analyses showed that male students in the program significantly outperformed their counterparts not in the program. In addition, larger proportions of male students reached a higher level of algebra understanding, compared with those not in the program. Different results were observed for female students in the program who did not significantly outperform their counterparts in the Comparison group. These findings appear to indicate that male students benefit from the program more than female students do.

The outcomes of the 2001 Norm-Referenced Component of the Florida Comprehensive Assessment Test show that students in both student groups achieved comparable levels of performance on both the Mathematics test and its Algebra component. Since this test contained only multiple-choice items, this finding agrees with the similar “no difference” outcome exhibited by students in the two groups on the multiple-choice part of the ETS Algebra I Test.

The end of year results indicate that students in the Program group had overall better final Algebra I grades than did their counterparts in the Comparison group. Somewhat larger proportions of program students passed the course, and slightly larger proportions of them earned grades of “C” or higher compared to non-program students.

The results of the assessment of student confidence about mathematics indicate that students in the program had a higher level of mathematics confidence than did their peers not in the program. At the same time, students’ opinions about the usefulness of mathematics did not differ significantly for students in the two groups.

Teacher survey results show that teachers had generally favorable opinions about the program. Most indicated that the program helped them to individualize their instructional practices, provided more time to assist students, and had an overall positive impact on student learning.

It should be noted that only one of the schools evaluated had a functional computer lab at the beginning of the 2000-2001 school year. Other schools had computers labs ready by October 2000. Therefore, the program might not have realized its potential fully, due to its somewhat delayed implementation

All these results appear to indicate that the program had a positive impact on student learning of Algebra. This beneficial effect was especially apparent for male students. Additionally, it appears that the program enhanced students’ confidence in their ability to learn mathematics and affected teachers’ instructional practices in a positive way.

Based on these findings, the following recommendations are offered:

1. Continue the Carnegie Learning Cognitive Tutor Algebra I Program in the schools involved.

2. Reevaluate the program during the 2001-2002 school year.

REFERENCES

Davidson, J. (1996). PUMPing students through the math pipeline. Carnegie Mellon Magazine, 15, 15-17.

Koedinger, R. J., Anderson, J. R., Hadley, W. H., & Mark, M. A. (1997). Intelligent tutoring goes to school in the big city. International Journal of Artificial Intelligence in Edication, 8, 30-43.

APPENDICES

APPENDIX A

Levels of Understanding

Advanced

Students at the *Advanced* level of understanding are not only able to work with algebra at an abstract level of understanding, but also have the ability to use algebra effectively to model and solve problems in context. They have a strong understanding of concepts and processes and can recognize, interpret, and represent relationships in multiple ways. They can consistently synthesize concepts, processes, and skills to solve complex and non-routine algebraic problems, and are highly competent in their ability to communicate with algebra. Their solutions are clearly presented, well organized, and complete. Answers or conclusions are always placed within the context of the problem, and all-important aspects of the problem are clearly addressed. Students at the *Advanced* level can consistently construct and generalize mathematical models for and within contextual situations; they display an ability to apply various types of reasoning to the problem-solving process.

Proficient

Students at the *Proficient* level can work with algebra at an abstract level of understanding. They exhibit conceptual understanding, can recognize relationships in multiple representations, and can synthesize concepts, processes, and skills, but usually within the realm of routine algebraic problems. They use algebraic notation correctly and accurately, and communicate algebraic relationships and processes. Their algebraic reasoning may be correct, but explanations are limited. Answers or conclusions, although usually correct, can be incomplete and may not always be placed entirely within the context of the problem. Students at this level can work with and interpret mathematical models consistently and, on occasion, can display the ability to construct a model for a contextual situation.

Basic

Students at the *Basic* level can work with algebra at a concrete or procedural level of understanding. They demonstrate proficiency with routine algebraic procedures and algorithms, such as solving a linear equation or solving a system of linear equations. Students at the *Basic* level have some understanding of concepts, but exhibit weaknesses in conceptual understanding. They can perform basic arithmetic computations and basic algebraic manipulations, as well as algorithmic procedures, but the overall presentation of algebraic ideas is not clearly presented and is difficult to follow. Students with a *Basic* understanding of algebra most often operate at a concrete, rather than an abstract, level and usually have difficulty making transitions between different modes of representation. They may be able to solve a problem in a context that has been recently discussed or is familiar to them, but are unable to transfer concepts and processes to new contexts.

Minimal

Students at the *Minimal* level seldom work beyond a concrete arithmetic level of understanding. They seldom demonstrate even partial comprehension of concepts and are unable to recognize concepts across different contexts. Their use of processes is limited, and they experience difficulty with even simple algebraic abstractions, procedures, and algorithms. Their use of algebraic notation is inconsistent. The algebraic knowledge that they communicate is often incomplete and lacking logical flow. Students at the *Minimal* level are unable to connect various representational modes to one another. Their work is primarily in one representational mode; they work almost entirely with numbers. They are unable to understand basic algebra concepts and processes in context.

APPENDIX B

MIAMI-DADE COUNTY PUBLIC SCHOOLS
OFFICE OF EVALUATION AND RESEARCH
CARNEGIE LEARNING COGNITIVE TUTOR ALGEBRA I PROGRAM
TEACHER QUESTIONNAIRE

INSTRUCTIONS: Please answer the following questions by checking an appropriate box. Your answers are confidential; only the averaged data will be reported.

	YES	NO
1. Were you trained on the Carnegie Learning Cognitive Tutor Algebra I program prior to the beginning of this (2000-2001) school year?	●	●
2. Did you participate in any training activities regarding the program during this school year?	●	●
3. Did you volunteer to participate in the program?	●	●
4. In your school, is the program implemented in accordance with its design? If NO, please explain in item 10 below.	●	●
5. Does the program give you an opportunity to adjust your instructional practices as a result of observing an individual student's process of problem solving?	●	●
6. Does the program give you more time to provide individual assistance to students?	●	●
7. Does the program make Algebra more interesting and/or relevant for students?	●	●
8. Does the program increase student motivation to learn Algebra?	●	●
9. Overall, does the program have a positive effect on student learning?	●	●

10. Please provide your comments or suggestions about the program, workbooks and software it uses, and its implementation in your school. **Use the other side of this paper if necessary.**

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APPENDIX C

TEACHERS' COMMENTS

1. We have not had full use of the computer lab because many computers were down for long periods of time.
2. Overall, I think that the program is a success. With some minor adjustments in the implementation process and some [elimination] of the program glitches, the program would have even [greater] success.
3. Due to our facility, it is difficult to schedule each class in the computer lab the required weekly minimum of 2 hours.
4. Computers were not operational for 1st nine weeks.
5. I like the program very much. The only problem I have [with it] is that the book does not explain problems in great detail. I would suggest that there be more examples on the book.
6. I think we should have been given a manual of mistakes that appear in the software prior to class meeting. It is very frustrating to have a student raise a question about something the computer does (or does not do) and you can't help or do anything about it. (Especially when 40 other kids are waiting for your guidance.)
7. Workbook was used sparingly – students were taken to lab only once a week after 1st semester. Group presentations were limited.
8. The computer lab is not available 2 times per week.
9. I think it is a good program. Some of my students say, "Math makes sense now".
10. Cognitive Tutor program is a great way of teaching Algebra because it's fun for the students and more. It gives students confidence in their mathematical abilities. It provides real-life problem situations. It helps each student individually. It covers less topics, and as a result, the students learn them better.
11. The Cognitive Tutor Algebra I program has a more relevant approach to Mathematics. The use of technology motivates students to learn. Because students are working at their own pace, they are more anxious to compete with their peers which reduces absenteeism and encourages students to be there before and after school. Teachers are also more willing to be there in the lab for students during this time because they can still prepare their lessons while supervising the students.
12. The program has provided the teacher with ammunition to combat the repetitive question of "where would I ever use Algebra I in my everyday life?"
13. I think the program has great possibilities. There were many computer program problem errors and the workbook doesn't cover all concepts we have previously taught in Algebra I. That would be OK except for the fact that the college bound student needs more Algebra. I think also that by starting out with so much reading on the computer, the ESOL student is somewhat at a disadvantage. I also think there is a great deal of the same kind of charting and graphing (somewhat like the "drill and kill" they always want teachers to get away from).
14. Ten computers were not set up… No room.
15. Overall, I think that the program is a success.

APPENDIX D

Mathematics Attitude Scale

DIRECTIONS: As you read each sentence, try to determine whether you agree or disagree with it and how strongly you feel about that sentence. Put an X in the box matching the best description of your feelings about each statement. Do not spend much time on any statement, ***but be sure to answer every statement.*** There are no "right" or "wrong" answers. The only correct responses are those that are true ***for you.*** Whenever possible, let the things that have happened to you help you make a choice.

	Strongly agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
1. I am sure that I can learn math.	●	●	●	●	●
2. My teachers have been interested in my progress in math.	●	●	●	●	●
3. Knowing mathematics will help me earn a living.	●	●	●	●	●
4. I don't think I could do advanced math.	●	●	●	●	●
5. Math will not be important to me in my life.	●	●	●	●	●
6. Males are not naturally better than females in math.	●	●	●	●	●
7. Getting a teacher to take me seriously in math is a problem.	●	●	●	●	●
8. Math is hard for me.	●	●	●	●	●
9. It's hard to believe a female could be a genius in mathematics.	●	●	●	●	●
10. I'll need mathematics for my future work.	●	●	●	●	●
11. When a woman has to solve a math problem, she should ask a man for help.	●	●	●	●	●
12. I am sure of myself when I do math.	●	●	●	●	●
13. I don't expect to use much math when I get out of school.	●	●	●	●	●
14. I would talk to my math teachers about a career that uses math.	●	●	●	●	●
	Strongly agree	**Agree**	**Neither Agree nor Disagree**	**Disagree**	**Strongly Disagree**

	Strongly agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
15. Women can do just as well as men in math.	•	•	•	•	•
16. It's hard to get math teachers to respect me.	•	•	•	•	•
17. Math is a worthwhile, necessary subject.	•	•	•	•	•
18. I would have more faith in the answer for a math problem solved by a man than a woman.	•	•	•	•	•
19. I'm not the type to do well in math.	•	•	•	•	•
20. My teachers have encouraged me to study more math.	•	•	•	•	•
21. Taking math is a waste of time.	•	•	•	•	•
22. I have a hard time getting teachers to talk seriously with me about math.	•	•	•	•	•
23. Math has been my worst subject.	•	•	•	•	•
24. Women who enjoy studying math are a little strange.	•	•	•	•	•
25. I think I could handle more difficult math.	•	•	•	•	•
26. My teachers think advanced math will be a waste of time for me.	•	•	•	•	•
27. I will use mathematics in many ways as an adult.	•	•	•	•	•
28. Females are as good as males in math.	•	•	•	•	•
29. I see mathematics as something I won't use very often when I get out of high school.	•	•	•	•	•
30. I feel that math teachers ignore me when I try to talk about something serious.	•	•	•	•	•
31. Women certainly are smart enough to do well in math.	•	•	•	•	•

	Strongly agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
32. Most subjects I can handle OK, but I just can't do a good job with math.	•	•	•	•	•
33. I can get good grades in math.	•	•	•	•	•
34. I'll need a good understanding of math for my future work.	•	•	•	•	•
35. My teachers want me to take all the math I can.	•	•	•	•	•

36. I would expect a woman mathematician to be a forceful type of person.	•	•	•	•	•
37. I know I can do well in math.	•	•	•	•	•
38. Studying math is just as good for women as for men.	•	•	•	•	•
39. Doing well in math is not important for my future.	•	•	•	•	•
40. My teachers would not take me seriously if I told them I was interested in a career in science and mathematics.	•	•	•	•	•
41. I am sure I could do advanced work in math.	•	•	•	•	•
42. Math is not important for my life.	•	•	•	•	•
43. I'm no good in math.	•	•	•	•	•
44. I study math because I know how useful it is.	•	•	•	•	•
45. Math teachers have made me feel I have the ability to go on in mathematics.	•	•	•	•	•
46. I would trust a female just as much as I would trust a male to solve important math problems.	•	•	•	•	•
47. My teachers think I'm the kind of person who could do well in math.	•	•	•	•	•